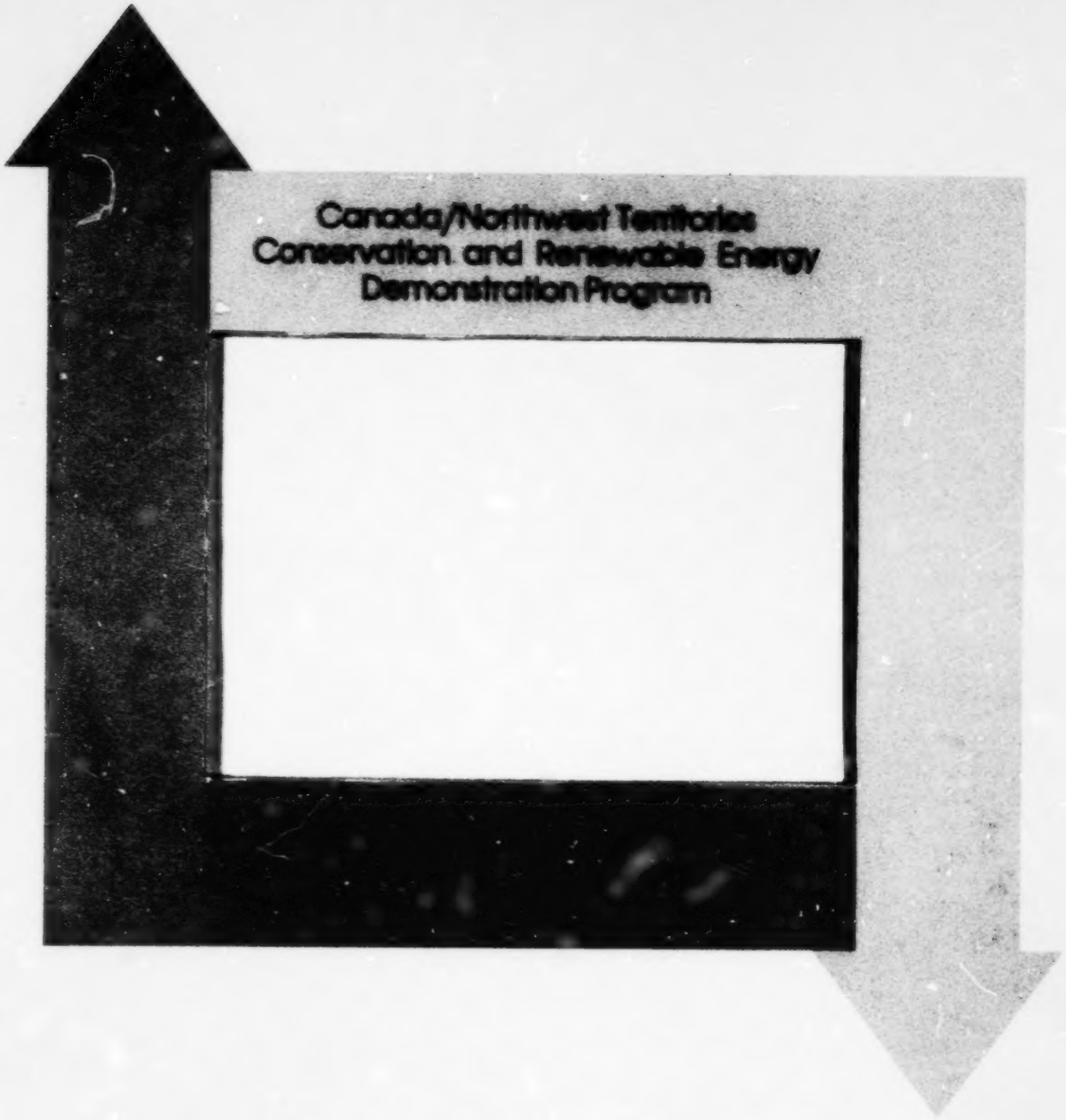
N.W.T.
6



Energy, Mines and Resources Canada

Energie, Mines et Ressources Canada

Northwest Territories Public Works

REFRIGERATION WASTE HEAT RECOVERY

Prepared By

FERGUSON, SIMEK, CLARK LTD

NORTHWEST TERRITORIES/CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of N.W.T. and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed March 24, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Cost-shared by the territorial and federal governments, the program has a total budget of $3.3 million.

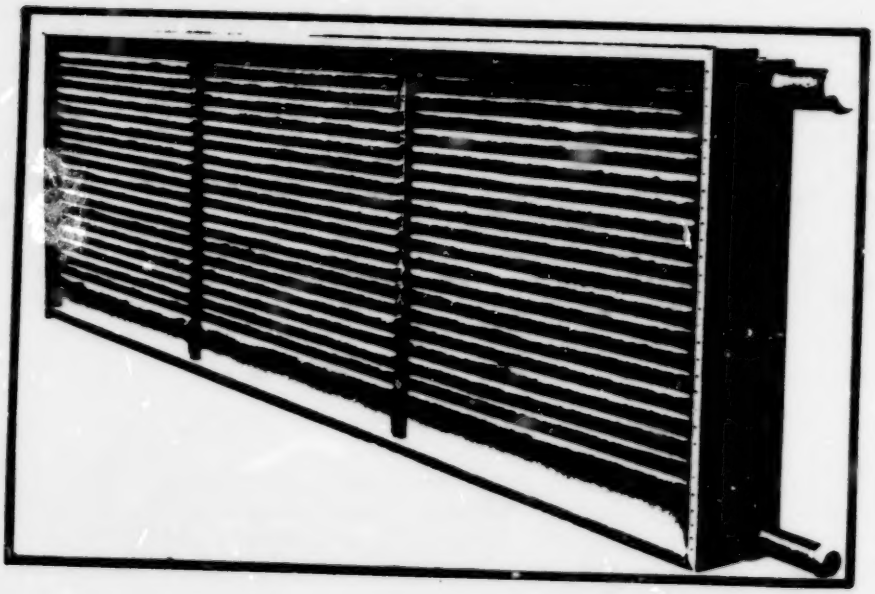
The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

YK SUPER A FOODS STORE
YELLOWKNIFE, N.W.T.

REFRIGERATION HEAT RECOVERY SYSTEM

ENERGY, MINES AND RESOURSES CANADA
&
ENERGY CONSERVATION DIVISION
DEPARTMENT OF PUBLIC WORKS
GOVERNMENT OF THE NORTHWEST TERRITORIES



THIS PROJECT WAS CONVENED BY CANADA/NORTHWEST TERRITORIES CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION PROGRAM

MARCH , 1983

FERGUSON, SIMEK, CLARK LIMITED
CONSULTING ENGINEERS & ARCHITECTS

4910-53rd STREET P.O. BOX 1977 YELLOWKNIFE, N.W.T. CANADA X1A 2P4

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1.0 SYNOPSIS

This report provides a description of a waste heat recovery system within a medium sized food store. It details how the waste heat that is produced by the conventional frozen food display cabinets, can be reused by the store's space heating system.

The refrigeration system was modified in late 1981, becoming operational in January 1982.

The CREDA Program, funded by the Government of the N.W.T. and Canada, contributed $17,444 towards the total project cost of $30,444. The project was initiated by the store owner, who is now realizing a lower annual fuel consumption, with the resulting financial savings.

This report was prepared by Ferguson, Simek, Clark Limited of Yellowknife, N.W.T., with the full co-operation of YK Super A Foods Store in Yellowknife.

1.0 SOMMAIRE

Ce rapport donne la description d'un système de recouvrement de chaleur résiduaire dans une épicerie. Il décrit en détail la manière dont l'on se sert pour recouvrire la chaleur produite par les coffrets congélateurs a manger et la faire re-circuler par le système de chauffage de la batisse.

Le système de réfrigération fut modifié vers la fin de 1981 et mis-en-opération en janvier 1982.

Le Programme CREDA, dont les fonds sont fournis conjointement par les Gouvernements des Territoires du Nord-Ouest et du Canada, ont contribué $17,444 des $30,444 du coût total du projet. Ce projet fut amorcé par le propriétaire de l'épicerie qui jouit présentement d'une épargne financière occasionnée par la dépense réduite du coût du chauffage.

Ce rapport a été préparé par Ferguson, Simek, Clark Limitée de Yellowknife, T.N.O., avec la coopération entière du Super-Marché Y.K. Super A de Yellowknife.

2.0 PROJECT SUMMARY

Background

Yellowknife is the Capital City of the Northwest Territories with a population of approximately 10,000. It is located on the Northside of the Great Slave Lake, 960 km. North of Edmonton.

The area has January mean high and low temperature of -23.4°C and -32°C respectively and July mean high and lows of 20.4°C and 11.3°C.

"YK Super A Stores" was built in 1972 and is part of a small indoor shopping complex linked together by a heated mall. The store has a public floor area of approximately 1,232 m^2 (13,261 $ft.^2$) and sells the usual variety of food produce including a large selection of frozen foods.

There are five lengths of refrigerated display cabinets with a total area of approximately 78 m^2. There are also some frozen food storage rooms at the back of the store.

The store provides one of the main shopping facilities in Yellowknife with opening hours 9:30 a.m. - 8:00 p.m., Monday to Saturday. The manager is totally involved in all aspects of the store, including a keen interest in the mechanical systems.

PROJECT MOTIVATION

As with the majority of heat recovery projects, the high cost of heating fuel was the main reason for its incorporation in this case.

The store owner was well aware of the potential savings of using the waste heat from the refrigeration equipment.

After consultations between the store, GNWT (Energy Conservation Division) and Consultants, Ferguson, Simek, Clark Limited, a financial and technical program was drawn up.

2.0 SOMMAIRE DU PROJET

ARRIERE-PLAN

Yellowknife est la capitale des Territoires du Nord-Ouest ayant une population d'environ 10,000 habitants. Elle est située sur la rive nord du Grand Lac des Esclaves a 960 km au nord d'Edmonton.

En janvier, les températures de la région varient entre -23.4C et -32C tandis qu'en juillet elles sont entre 20.4C et 11.2C.

Le super-marché "Y.K. Super A" a été construit en 1972. Il fait parti d'un centre d'achat et est rejoint par un corridor chauffé. L'épicerie couvre une étendue d'environ 1,232 m.carre (13,269 pi.carre) et vend une sélection variée d'épiceries et produits congelés.

Il y a cinq unités de coffrets congélateurs ayant une capacité de 78m/carré. Il y a aussi des chambres congélatrices a l'arrière du magasin.

Ce magasin est un centre d'achat des plus importants de Yellowknife ses heures d'affaire étant de 9:30 a.m. a 8:00 p.m., du lundi au samedi. Le gérant est impliqué dans tous les aspects du magasin et porte un intérêt tout particulier aux systèmes mécaniques.

MOTIVATION DU PROJET

Comme dans la majorité des cas, le coût élevé du chauffage a été la raison principale du développement de ce projet de recouvrement de chaleur.

Le propriétaire du magasin était bien conscient du potentiel d'épargne qui existait dans la récupération de la chaleur résiduaire de l'équipement de réfrigération.

Suivant les consultations entre le magasin, GTNO (Departement de la Conservation de l'Energie) et les Conseillers, Ferguson, Simek, Clark Limitee, un programme financier et technique fut rédigé.

PROJECT DESCRIPTION

In a refrigeration circuit, the air within the frozen food cabinets gives up its heat to the freon which is flowing through coils specifically designed for this purpose. The freon then takes this heat away from the cabinets and discharges it to outside, in this case via an air-cooled condenser.

The main idea behind this project was to use this waste heat for heating the store itself. The obvious solution was to provide an alternative path for the refrigerant, divering it to the store's air handling equipment, where the freon heat could be transferred to the store's air supply. The air handling equipment is situated approximately 30 metres from the refrigerant compressers.

Two new heat reclaim coils were installed in the store's return air duct (one coil for each refrigerant system) and a heat reclaim valve was installed in each system which acts as a control. The valve diverted the freon to the heat reclaim coil, when the store required heat and it discharged the freon up to the roof air condenser in the traditional way, when the store was satisfied.

This installation worked well, satisfying the heat requirements of the store's air supply system in winter and using the condensers in summer, when necessary. The store manager, however, saw potential for upgrading the system still further. His main complaint was that the operation of the on/off control for the condenser fans was manual and he found that he would leave the fans running for most of the time for his peace of mind. In order to partially rectify this situation, in October 1982, additional controls were incorporated into the system. This consisted of a pneumatically controlled thermostat sensing the temperature within the air plenum immediately before the supply fan. This control modulates the exhaust, return, and fresh air dampers to achieve the desired temperature setpoint (in this case 21°C). By installing this additional control, the manager expected the flow of freon to always be directed to the heat reclaim coil. During the periods when the store does not require the total heat from the freon, the exhaust damper opens and the correct mix of return air with fresh air produces the desired 21°C supply air.

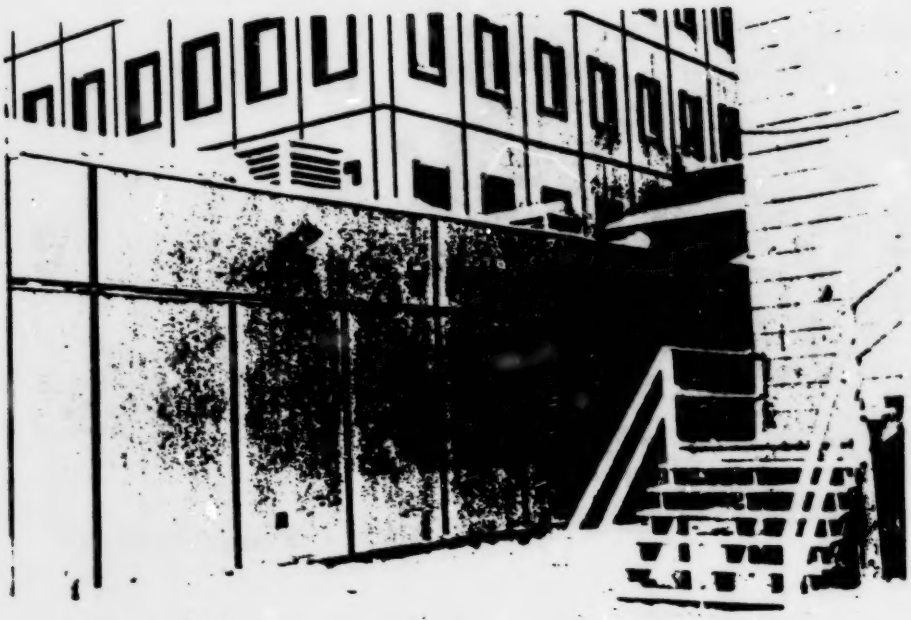
This is the present condition of the system but it is now proposed that there is an additional modificiation. Even though the refrigerant is expected to be sufficiently cooled by the return air, the roof mounted condenser still acts as a standby in case of R/A fan breakdown, or if it is needed in the height of summer. The fact is that if there was a breakdown in the cooling of the freon, there would be disastrous consequences and so the manager prefers to keep the condenser fans running just in case of an emergency. This is obviously very wasteful of electricity and it is proposed to install a pressure switch into the freon pipeline which shall automatically turn on the condenser fans, if necessary.

Once the pressure switch is installed, the system shall then be totally automatic, minimizing the electrical and heating loads of the mechanical system.

SYSTEM INSTALLATION

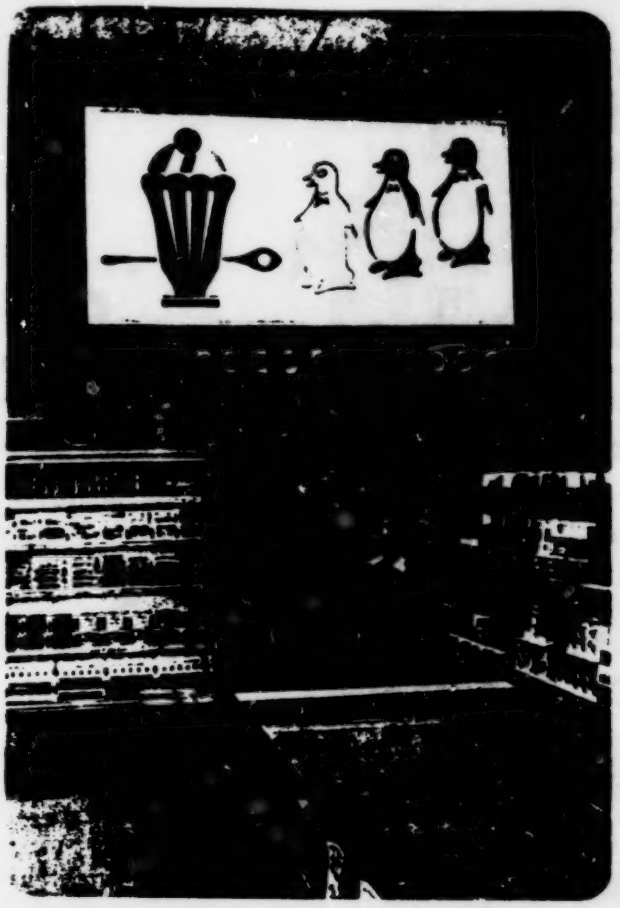
The installation of the heat recovery equipment was straightforward, with good workmanship. The system worked as expected from the beginning.

"YK SUPER A FOODS STORE" IN CENTRAL YELLOWKNIFE



EXHAUST AIR WALL LOUVRE & ROOF AIR INTAKE

ROOF MOUNTED CONDENSER UNIT.



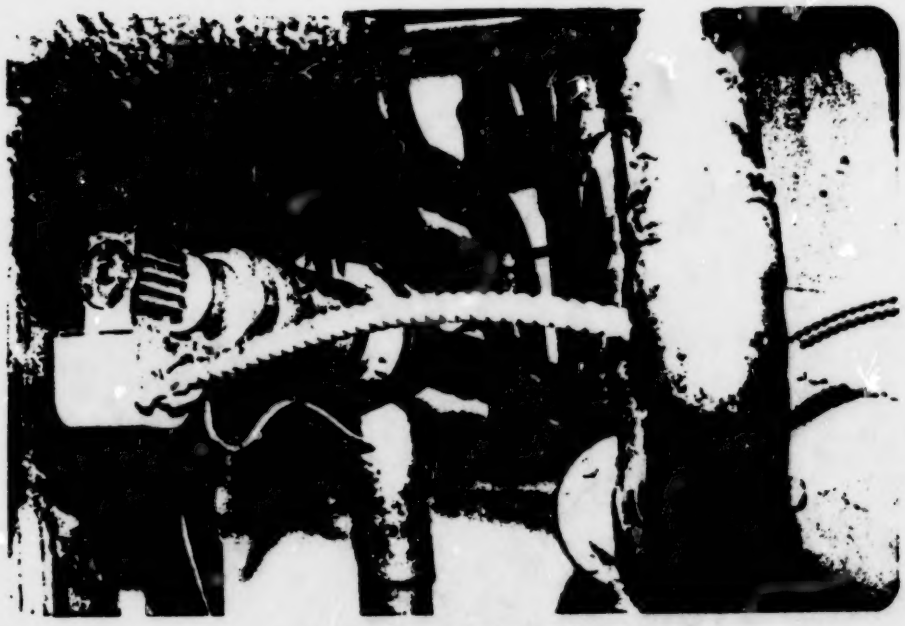
REFRIGERATED FOOD UNITS. R/A GRILLE RUNS ABOVE SIGN.

STORE THERMOSTAT CONTROLLING REHEAT AIR COIL.

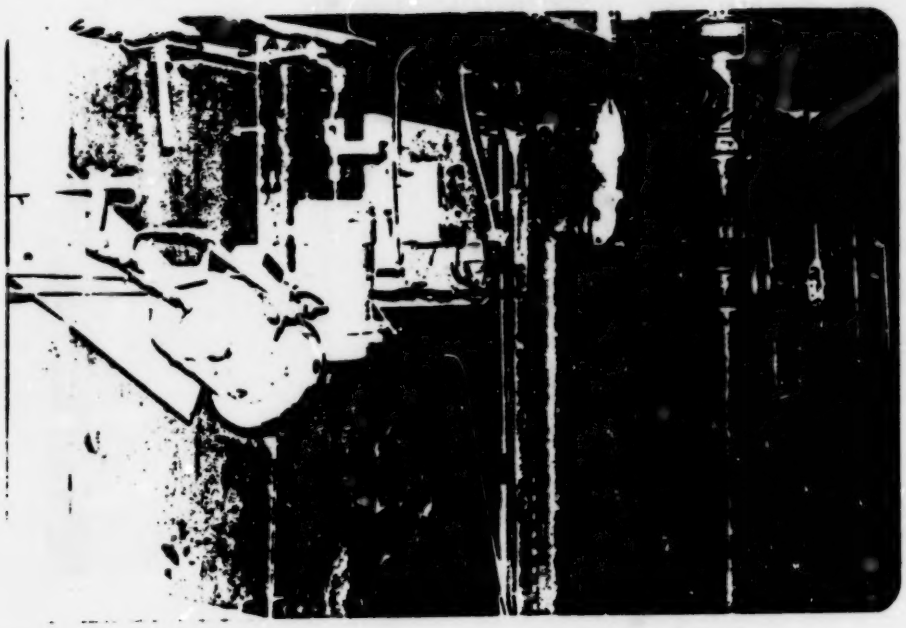
REFRIGERATION COMPRESSORS & CONTROL PANEL IN BASEMENT.

LIQUID & SUCTION PIPES RUN TO HIGH LEVEL FROM BASEMENT.

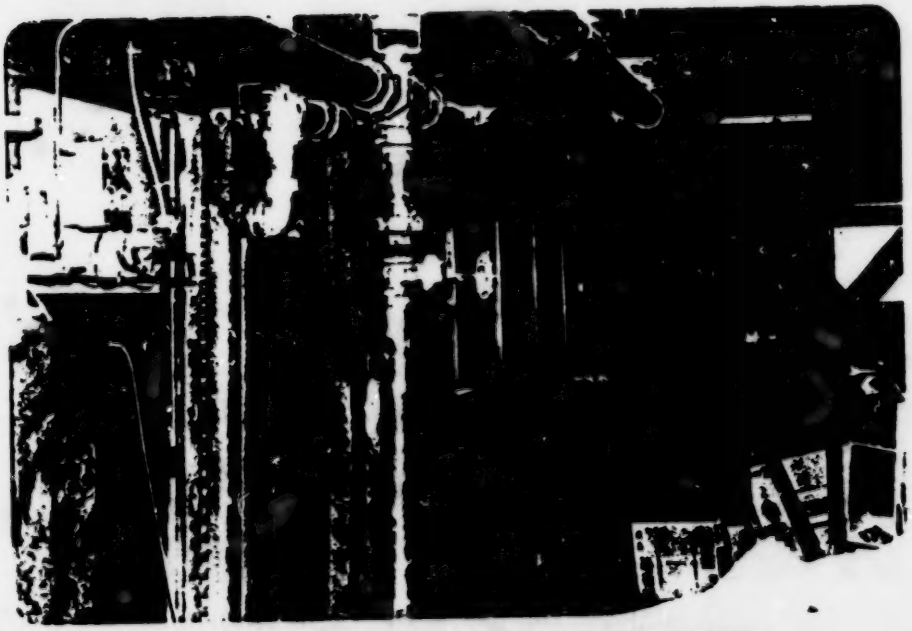
RETURN AIR PLENUM & HEAT RECLAIM COIL



HEAT RECLAIM VALVE IN COMPRESSOR ROOM



FRESH AIR & RETURN AIR DAMPERS MOTORS
PRECEDING REHEAT COIL



SUPPLY AIR UNIT & DUCTWORK INTO STORE

4.0 MONITORING AND TECHNICAL SECTION

Approach

Our main source of information came from the store manager and from our observations of the system at various outside temperatures. Temperature readings were taken to see how the new heat reclaim coil was performing.

Readings and Analysis

During the winter, readings T1 and T2 (see Figure 3) were taken over an outdoor temperature range of $-4^{\circ}C$ to $-40^{\circ}C$.

The readings were T1 = $20^{\circ}C$
T2 = $27.2^{\circ}C$

Over the large outdoor temperature range, the readings T1 and T2 did not change significantly.

The supply air temperature setting for the store is $21.1^{\circ}C$, and it can immediately be seen from the following section that the bulk of the heat given up by the freon, is not used by the store.

The fresh air damper does not have a minimum setting as the exit doors into the mall are permanently open during the day allowing sufficient infiltration here.

The supply air temperature control modulates the three dampers, and we checked to see that this control operated satisfactorily. At a setting of $32^{\circ}C$, both the exhaust and fresh air dampers closed completely, with the return air being recirculated into the store. In this situation, the reheat coil was required to make up the air temperature from $27.2^{\circ}C$ to $32^{\circ}C$.

At a supply air setting of $4^{\circ}C$, the exhaust damper opened to 80% full opening and the fresh air opened 20%. The outside air temperature was $-30^{\circ}C$ and so very little of this air was required to mix with the return air, in order to bring the temperature down to $4^{\circ}C$.

5.0 ENERGY SAVINGS ANALYSIS

1. Oil Savings

The total heat recovered

from the refrigerant is: = 7.55 x 1.24 x (27.2 - 20)
= 67.41 KW

This heat is not totally utilized, the majority having to be exhausted to outside as the store can not practically use this excess heat.

The store supply air is set at 70°F (21.1°C) and the return air remains steady at 68°F (20°C) throughout the heating season. We found that the return air temperature did not change significantly as the outside air temperature changed. This tells us that the major heating load is handled by the hot water heating at the front of the store and the separate warm air system at the rear.

The actual saving from the heat reclaim coil, during the day, is just the heat necessary to reheat the R/A from 20°C to 21.1°C.

Heat Recovery: = 7.55 x 1.24 x (21.1 - 20)
= 10.30 KW

The heating coil would normally only be required for approximately 9 months of the year (being mostly unnecessary in June, July, and August).

Total Savings: = 10.30 x 24 hours x 303 days
= 74,902 KWh

During the winter months at night, the store is supplied with warm air to prevent freezing. There are three factors to consider affecting the heating load at night.

1. There is only minimum lighting between 9:00 p.m. and 9:00 a.m. A conservative estimate of the daytime lighting load is 15 watts per square metre.

2. At nights there are no shoppers. The average heat output from the human body is 100 W+. We feel, however, that this heat input to the store is equally offset by the cold that would radiate from the shoppers' clothing.

Infiltration at the doorways is kept to a minimum at night. This does not seem to be significant, however, because one exit is connected to the heated mall while at the other, air flow appears to be directed out of the pressurized store.

The infiltration at the loading bays is handled by the separate warm air supply heated through its own reheat coil.

The heat from the lighting, therefore, is the only load that shall be considered. The return air flow is at high level and has to pass directly across the lighting. We feel that the lighting load, which during the day is absorbed by the return air has to be made up by the heat reclaim coil at night.

Lighting load: = 1,232 m^2 x 15 W
= 18.48 KW

This 18.48 KW load is a direct saving and occurs for approximately 7 months of the year when the supply fan is operating.

So night savings = 18.48 KW x 2,332 hours
= 43,095 KWH

So fuel savings = $\frac{43,095}{8.56}$

= 5,035 Litres of oil

2. Electrical Savings

Without the automatic pressure switch that the store manager proposes to install, the condenser fans are presently kept running in case of R/A fan failure.

It is realized that this is extremely wasteful and we feel that in the future with the automatic control, the condensers shall never be required to operate. In summer the heat drawn from the freon, into the store return air, shall be totally exhausted to outside while the store operates on 100% fresh air.

Before the heat recovery installation, the R/A fan (together with the supply air fan) was shut down for approximately 5 months of the year at night, during the hours 9:00 p.m. to 8:00 a.m. (11 hours).

Over these five months the R/A fan operation saving:

= 153 days x 11 hours
= 1,683 hours

Now that the R/A fan is necessary to draw air across the heat reclaim coil, an additional running cost is incurred.

Additional electrical consumption @ 5 HP=1,683x3.73 KW
= 6,278 KWH

The advantage of continuously running the R/A fan though, is that the condenser can be turned off and in the future we feel that the condenser operation will be unnecessary, or least bat e kept to an absolute minimum.

Saving from condenser @ 3 HP = 365 x 24 x 2.24
= 19,622 KWH

6.0 FINANCIAL SAVINGS SUMMARY

Parameters for Calculations: Heat output of No. 2 heating coil at 80% efficiency is 8.56 KWH per litre.

: Cost of oil in Yellowknife (1983) is 35.1 ¢ per litre.

: Cost of electricity in Yellowknife (1983) is 10.12 ¢ per KWH.

1. Upgrading of Ventilation System

Supply air heating coil: Required for 9 months/year in daytime.
Required for 7 months/year at night.

So the total operating hours for the supply air system were approximately 5,448 hours.

Heat output of coil = 10.30 KW
Total energy/year = 10.30 x 5,448
= 56,114 KWH

The heat reclaim coil completely replaces the heat output of the heating coil.

So fuel saving = $\frac{5,6114 \text{ (KWH)}}{8.56 \text{ (KWH/litre of oil)}}$

= 6,555 litres of oil

2. Condenser Operation

Previously the condenser operated 24 hours per day all year round, @ 3 HP.

Electrical Load = (3 x 0.746) x 24 x 365
= 19,622 KWH

Once the pressure switch in the condenser pipeline is installed, the condenser operation will be minimum and probably shall not be needed at all.

The 19,622 KWH shall be a direct saving.

The drawback of not using the condenser is that the R/A fan now operates 24 hours per day, all year round.

From the energy saving analysis section, it is seen the R/A fan now operates 24 hours per day @ 5 HP.

So the additional electrical load	= (5 x 0.746) x 1,683 = 6,278 KWH
So the electric load saving	= 19,622 - 6,278 = 13,344 KWH

Total Savings

The total savings realized from the heat recovery project are as follows:

Fuel Savings:	Daytime Savings 6,555 litres x 35.1¢	= $2,300/year
:	Night Savings 5034 litres x 35.1¢	= $1,767/year
Electrical Savings	13,344 KWH x 10.12¢	= $1,350/year
	Total Savings	= $5,417/year

7.0 RECOMMENDATIONS

1. Our observations have indicated that heat recovery would prove to be economical to similar stores right across Canada. The waste heat available from the refrigeration system far exceeds the heat requirements of the ventilation system and other stores may find that their air system demands are greater. The project payback period in this case is 4 to 5 years but this shall vary in other stores with the total capital invested in the equipment and the amount of the waste heat which can be used by the store.

2. There is excess heat given off by the refrigeration system all year round. At present this heat is partially used for the store's main floor heating, but our observations show that even in winter at $-40^{\circ}C$, excess heat is still produced.

   In this particular store this heat could be used in a number of ways.

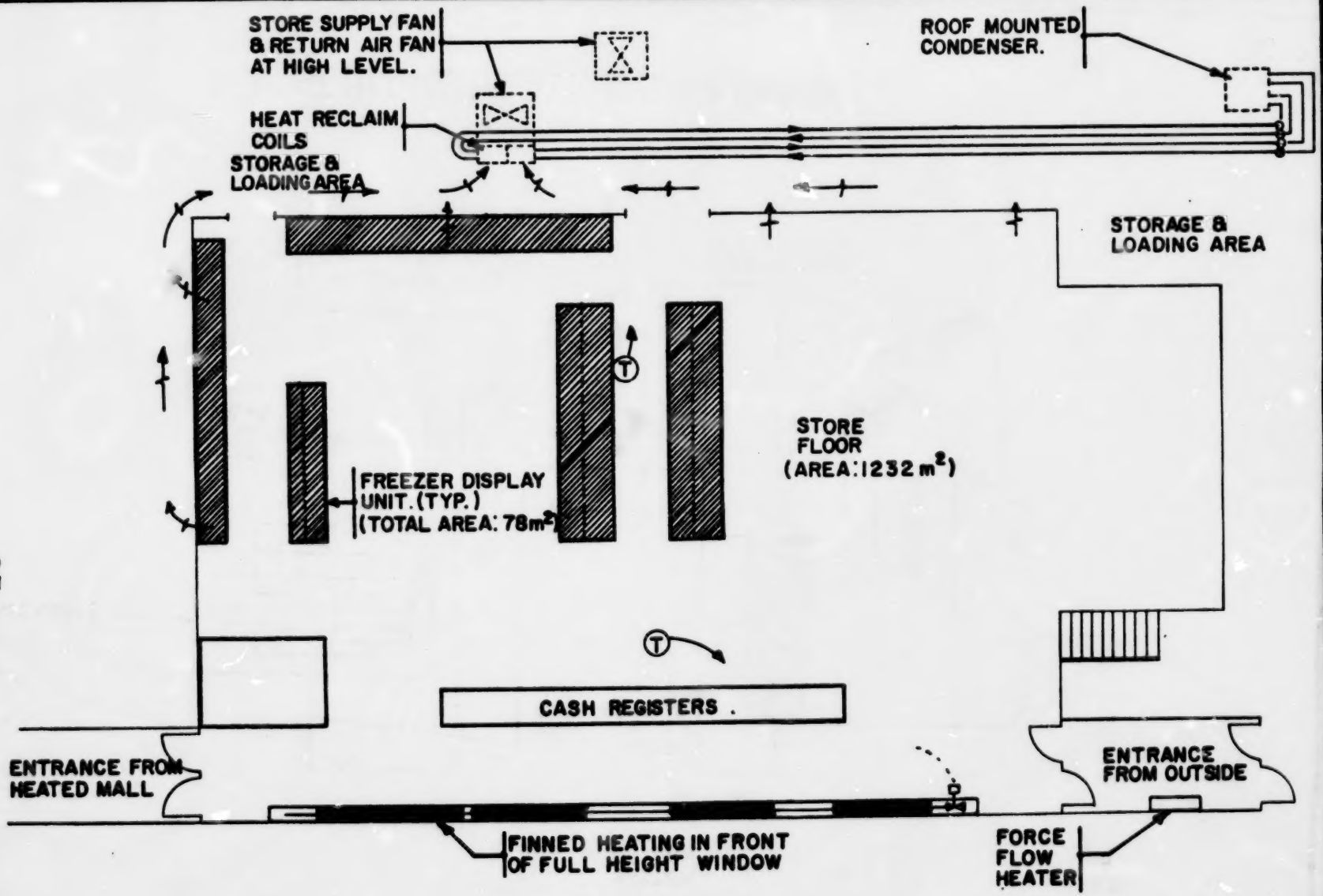
   1. The heat could be diverted to the loading bays which would make the present loading bay reheat coil unnecessary.

   2. The heat could be ducted to the front of the shop and discharged at low level. At present, a separate hot water system handles the conduction and infiltration loads in this area.

   3. The heat could be used for the adjacent shopping mall.

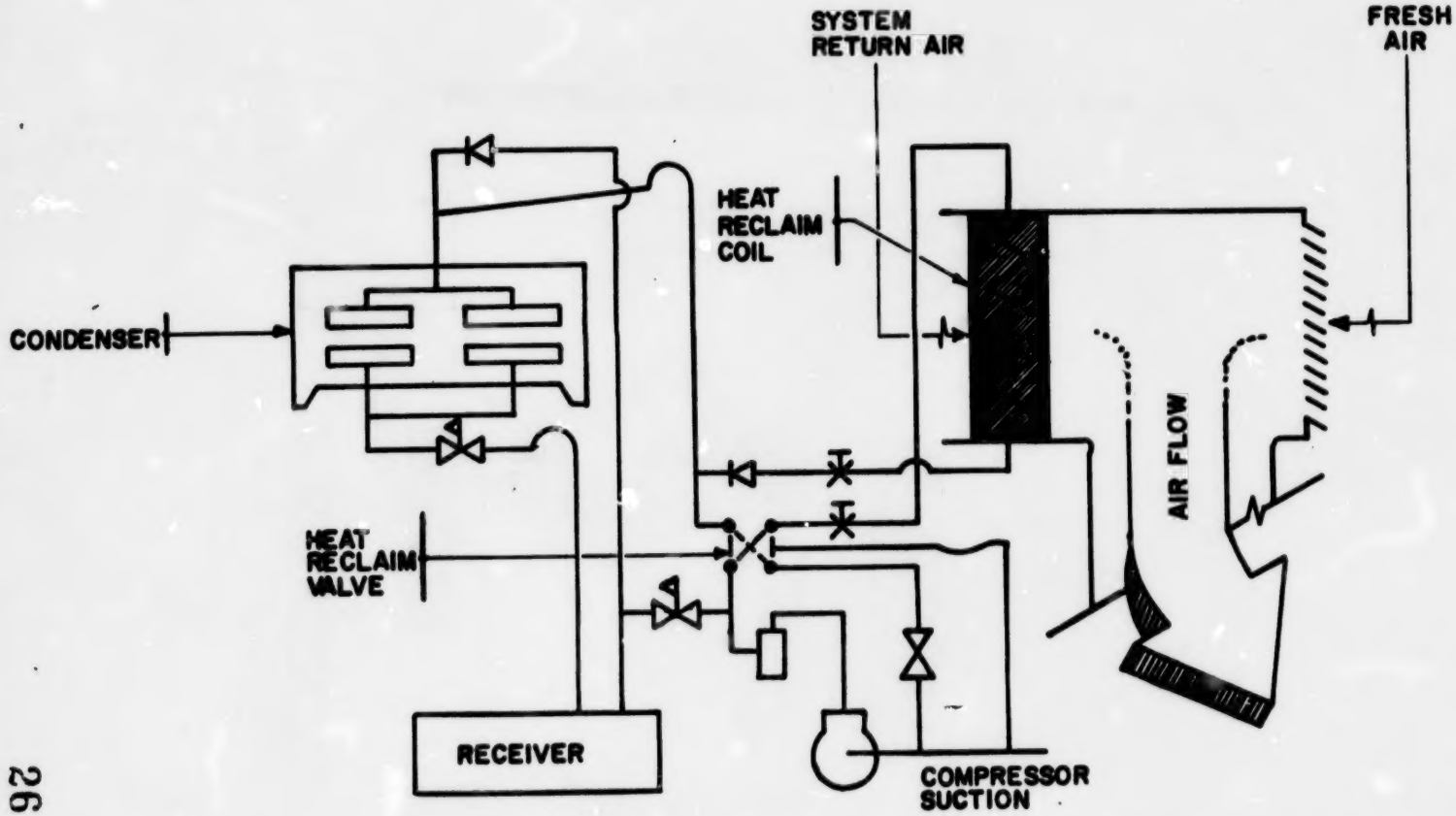
   Often in retrofit work though, the savings are not large enough to warrant the additional cost and because of this, the above proposals are probably economically unviable. However, when new stores are in the design stage, or where other existing stores offer more flexible possibilities, the full potential of the waste heat available should be taken into consideration.

3. An automatic control should be incorporated into the condenser system so that the fans do not have to operate when cooling of the freon is not required.


STORE SUPPLY FAN & RETURN AIR FAN AT HIGH LEVEL.
ROOF MOUNTED CONDENSER.
HEAT RECLAIM COILS
STORAGE & LOADING AREA
STORAGE & LOADING AREA
T
STORE FLOOR (AREA: 1232 m²)
FREEZER DISPLAY UNIT. (TYP.) (TOTAL AREA: 78m²)
T
CASH REGISTERS .
ENTRANCE FROM HEATED MALL
ENTRANCE FROM OUTSIDE
FINNED HEATING IN FRONT OF FULL HEIGHT WINDOW
FORCE FLOW HEATER

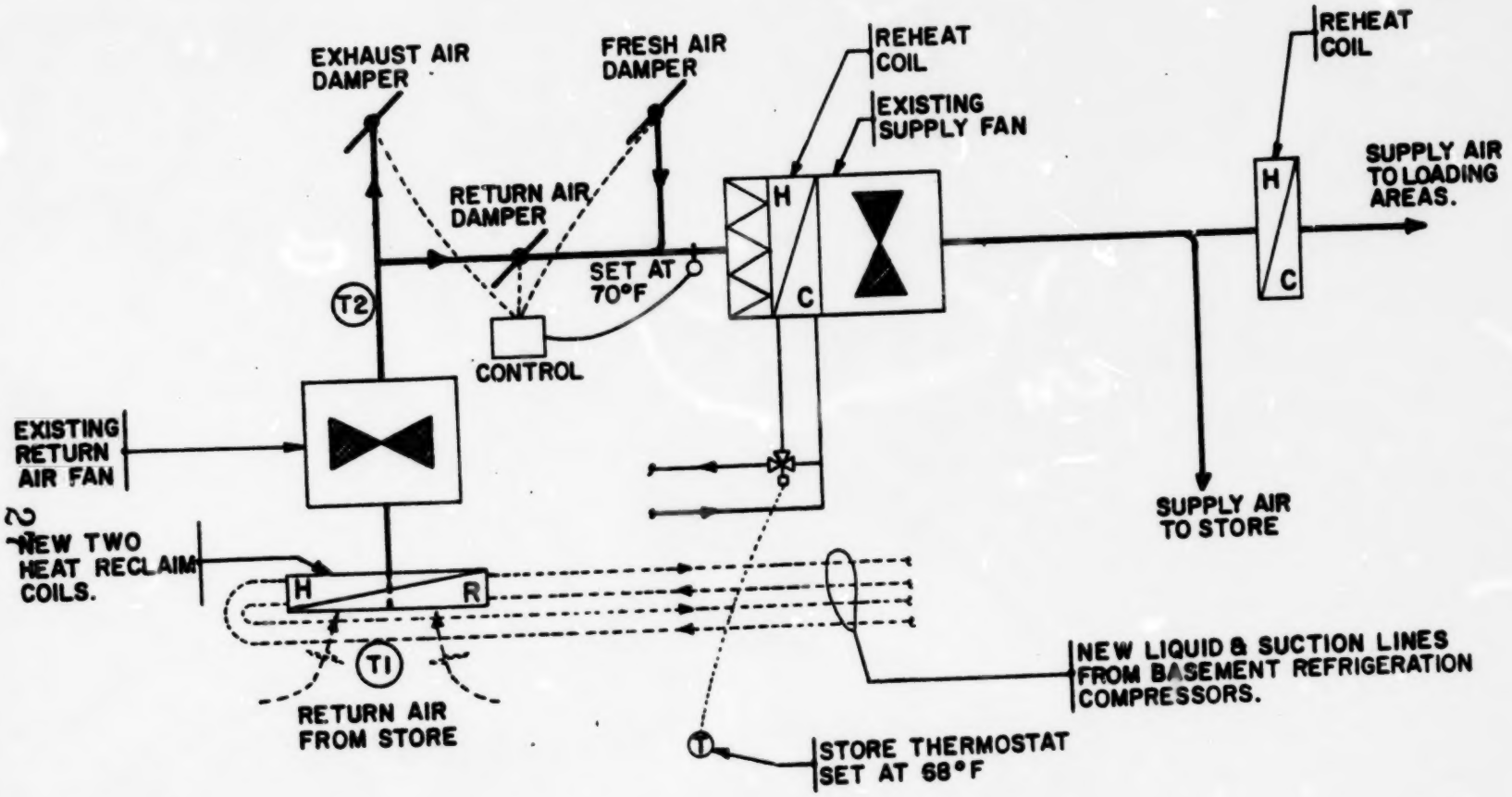
LAYOUT OF STORE
N.T.S.

FIG. 1



HEAT RECOVERY SYSTEM SCHEMATIC
N.T.S.

FIG. 2



AIR HANDLING EQUIPMENT DETAILS

N.T.S.

FIG.3

ORIGINAL FORECAST

WASTE HEAT RECOVERY - COST AVOIDANCE BENEFITS

YK SUPER A FOODS LTD HEAT RECOVERY

PRESENT VALUE - CAPITAL INVESTMENT = $ 22000.00

F I N A N C I A L E V A L U A T I O N

PAYMENT NO.		TOTAL FUEL SAVING PV		PRINCIPAL OUTSTANDING PV
1	$	7413.13	$	14586.87-
2	$	15092.39	$	6906.61-
3	$	23050.43	$	1050.43
4	$	31294.20	$	9294.20
5	$	39835.05	$	17835.05
6	$	48683.67	$	26683 67
7	$	57851.17	$	35851.17
8	$	67349.02	$	45349.02
9	$	77189.14	$	55189.14
10	$	87383.86	$	65383.86
11	$	97945.95	$	75945.95
12	$	108888.66	$	86888.66
13	$	120225.71	$	98225.71
14	$	131971.29	$	109971.29
15	$	144140.14	$	122140.14
16	$	156747.51	$	134747.51
17	$	169809.20	$	147809.20
18	$	183341.57	$	161341.57
19	$	197361.60	$	175361.60
20	$	211886.86	$	189886.86

TOTAL FUEL SAVING = 31648. LITRES PER YEAR
DISCOUNT RATE - 11 %; FUEL INFLATION RATE - 15 %

BREAK - EVEN AT YEAR 8

WASTE HEAT RECOVERY FINANCIAL ANALYSIS (Based on Field Results)

Present Value - Capital Investment = $30,444.

Payment No.	Total Fuel Saving(PV)	Principal Outstanding(PV)
1	6,230	24,214
2	12,730	17,714
3	19,535	10,909
4	26,657	3,787
5	34,094	3,540 -
6	41,864	11,420 -
7	49,998	19,554 -
8	58,504	28,060 -

Discount Rate = 10%.
Break-even at year 5

With the present unstable economic situation the above forecast can only be an estimate.

EQUIPMENT

Store Supply Air Fan:	7.55 m^3/s c/w 7.46 KW motor.
Store Return Air Fan:	7.55 m^3/s c/w 3.73 KW motor.
Refrigeration Condenser:	4 fans @ 1.12 KW each.
Refrigeration Compressors:	4 compressors @ 5.60 KW on low temp. circuit (R502).
:	4 compressors @ 7.46 KW on medium temp. circuit (R22).

11.0 REPORT DISTRIBUTION

It is suggested that the distribution of the report should include the following:

1. Engineering Societies and Trade Associations

    1. American Society of Heating Refrigerating and Air Conditioning Engineers Incorporated,
    345, East 47th Street,
    New York, N.Y. 10017.

    2. Air Conditioning and Refrigeration Wholesale Association,
    22371, Newman Avenue,
    Dearborn, Michigan 48124.

    3. National Association of Food and Dairy Equipment Manufacturers,
    5530, Wisconsin Avenue,
    Washington, D.C. 20015.

    4. National Commercial Refrigeration Sales Association,
    1900, Arch Street,
    Philadelphia, Pennsylvania 19103.

    5. Practical Refrigerating Engineers Association Incorporated,
    4906, Wrightwood Avenue
    Chicago, Illinois 60639.

2. Refrigeration Equipment Manufacturers

    1. Coldmatic Refrigeration of Canada Limited,
    4500 Chesswood Drive,
    Downsview, Ontario M3J 2B9.

    2. Hussman Refrigerator Company,
    Bridgeton, Missouri.

    3. Coldstream,
    1855, Sargent Avenue,
    Winnipeg, Manitoba R3H 0L3

    4. Dunham Bush of Canada Limited,
    Head Office,
    140, Wendell,
    Toronto, Ontario.

3. Chain Food Store Corporations

1. IGA Canada Limited,
Canadian Headquarters,
170, Attwell,
Toronto, Ontario.

2. Loblaws Limited (Head Office),
22, St. Clair East
Toronto, Ontario.

3. Miracle Food Mart (Head Office),
65, Rexdale Boulevard,
Toronto, Ontario.

4. Dominion Dairies Limited,
Head Office,
235, Walmer Road,
Toronto, Ontario.

5. Dominion Stores Limited,
Executive Offices,
605, Rogers,
Toronto, Ontario.

4. Journals

1. Canadian Business Magazine,
CB Media Limited,
70, The Esplanade,
Suite 214,
Toronto, Ontario M5E 1R2.

2. Canada Commerce,
Department of Industry Trade and Commerce,
Ottawa, Ontario K1A 0H5.

3. Marketing,
MacLean-Hunter Limited,
481, University Avenue,
Toronto, Ontario M5W 1A7.

4. La Revue Commerce,
1080, Cote du Beaver Hall,
Montreal, Quebec H2V 1T1